ENHANCED SNOW COVER ALGORITHM BASED ON 250 M MODIS IMAGES FOR MONITORING TEMPORAL AND SPATIAL CHANGES IN THE MOUNTAIN AREAS

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Motivation and outline

- The snow covered area (SCA) is a key parameter for many applicative domains, such as hydrology, meteorology and climatology due to its impact on water availability and Earth radiation budget

- The MODIS MOD10 and MYD10 snow products have demonstrated good performances, even though some limitations are found in the case of local and regional monitoring, especially due to ground resolution of 500 m.

- The 500 m resolution can bring to some misclassification errors related to the inherent presence of mixed pixels in the case of patchy snow, especially in small mountain catchments.

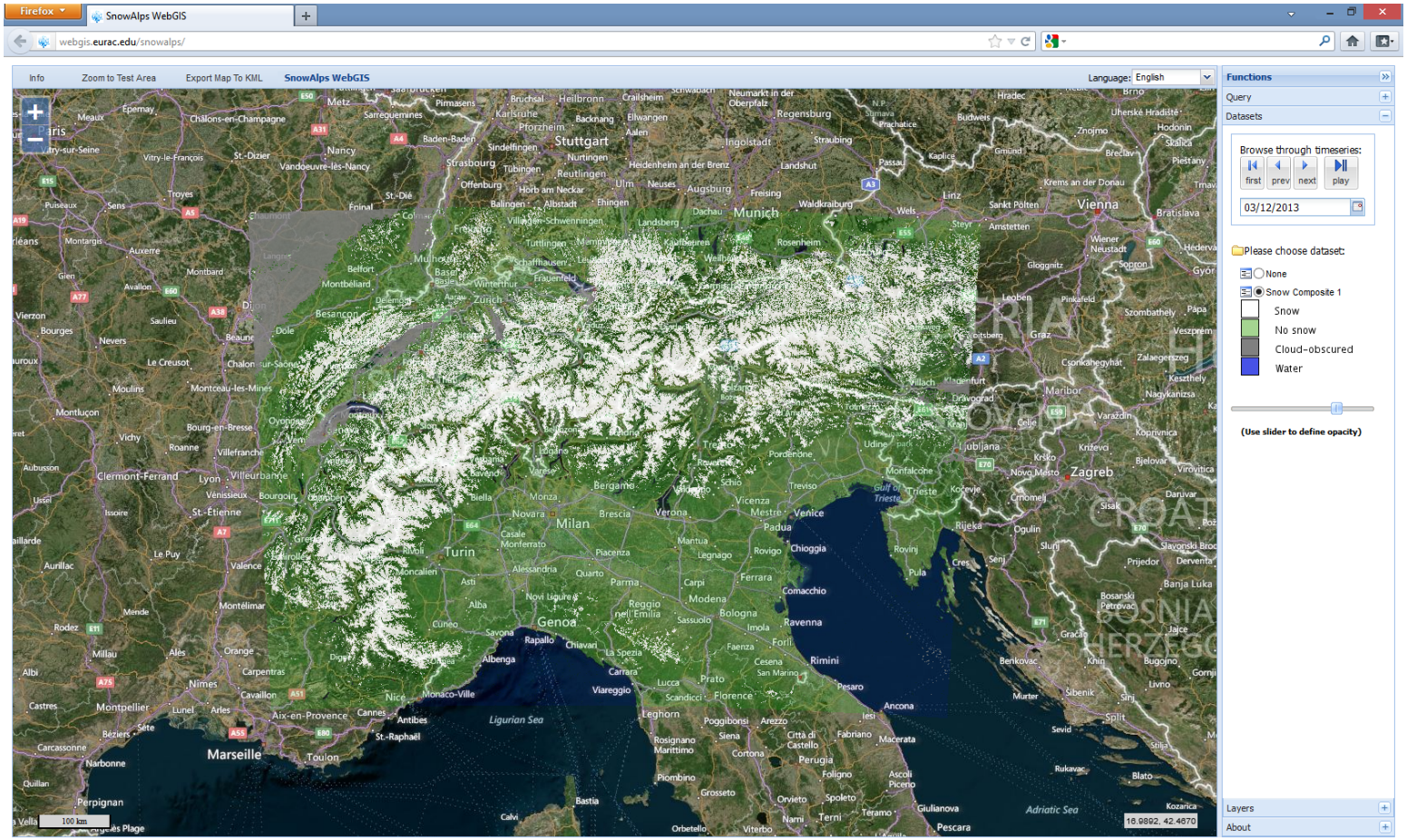
- A new algorithm is presented which determines SCA from MODIS images **at 250 m:**

  - Algorithm description – main concept and implementation
  - Validation activities
  - Applications to spatial and temporal snow monitoring

Product Specifications

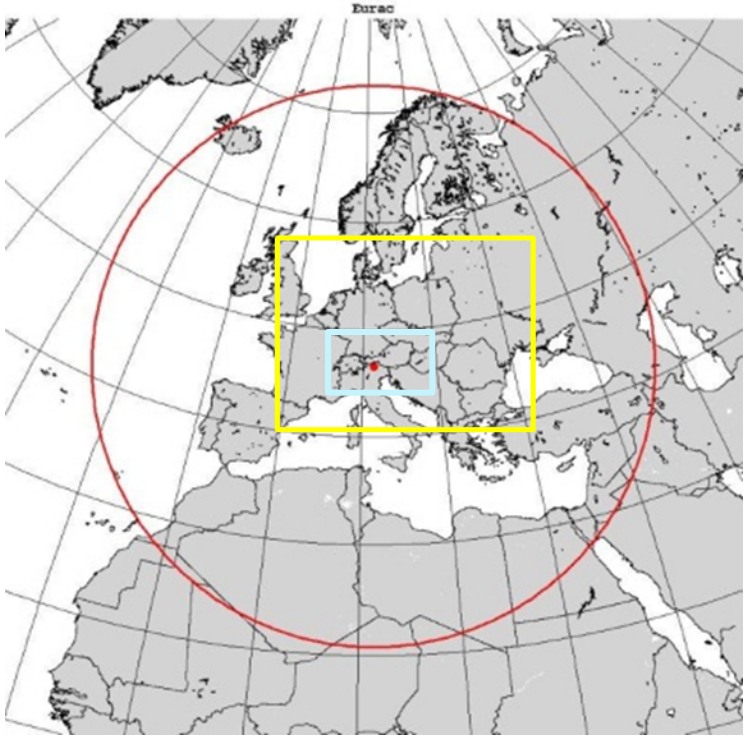
Product Name	EURACSnowAlps
Sensor and applied spectral bands	MODIS, band 1 (RED) and band 2 (NIR) (for snow)
Temporal Characteristics	
Period (Start – End)	2002-2014
Temporal resolution (1 day, 1 week, ..)	Daily
Spatial Characteristics	
Spatial resolution / Pixel size	250 m (snow), 1 km (cloud)
Spatial Coverage	Alpine Arch (43°-48° N / 5°-15°E)
Map Projection / Datum	UTM, WGS 84
If applicable: Cloud screening	
Algorithm	Adapted NASA algorithm MOD/MYD35 for Alpine areas
If applicable: Valid / non-valid areas	
Invalid/masked areas	
Product Format	GEOTIFF
Products accessible at	*http://* webgis.eurac.edu/snowalps/
Contact Person Name email	 Claudia Notarnicola claudia.notarnicola@eurac.edu

Snow maps webgis EURAC



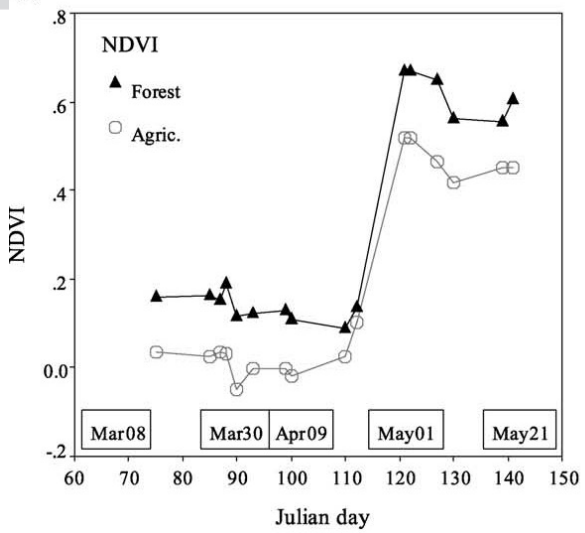
http://webgis.eurac.edu/snowalps/

Product Area of Interest

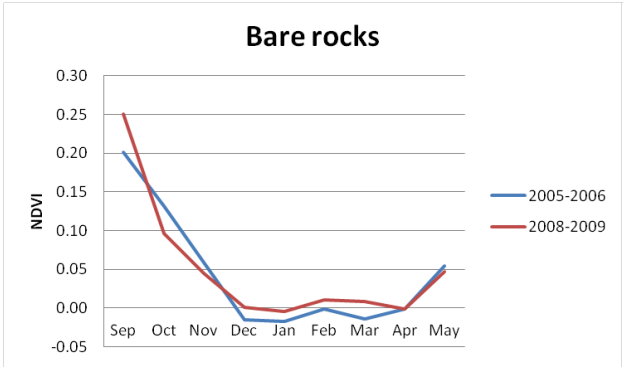


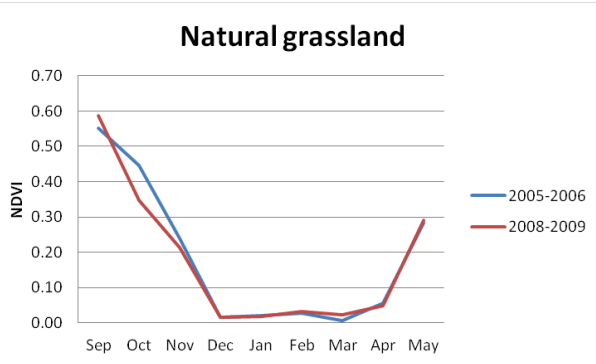
Red: footprint of the antenna
Yellow: snow maps available for 2005-2006
Blue: snow maps available for 2002-2014

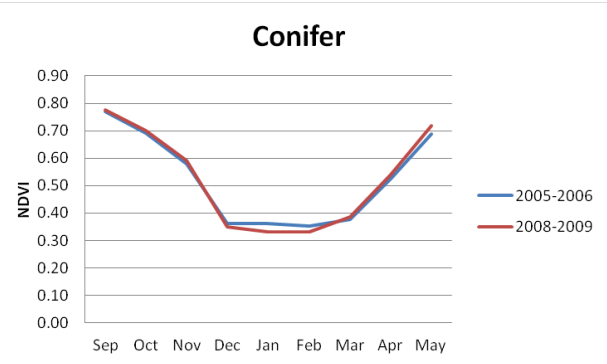
Snow cover retrieval concept



Methodology proposed is adapted from Metsämäki et al., 2002 and Malcher et al., 2003

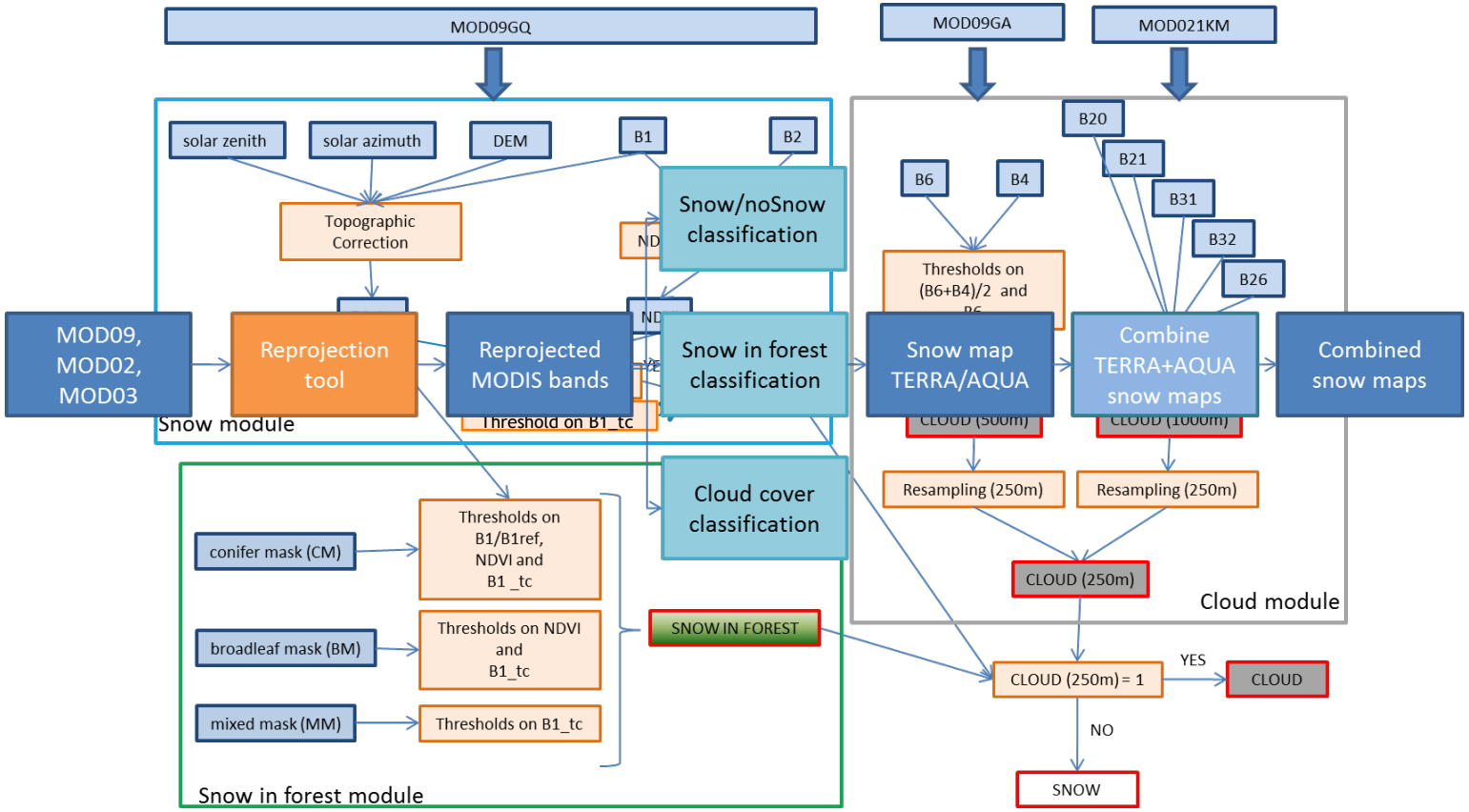






Notarnicola, C.; Duguay, M.; Moelg, N.; Schellenberger, T.; Tetzlaff, A.; Monsorno, R.; Costa, A.; Steurer, C.; Zebisch, M. Snow Cover Maps from MODIS Images at 250 m Resolution, Part 1: Algorithm Description. *Remote Sens.* **2013**, *5*, 110-126.

Snow cover retrieval algorithm



Input and auxiliary data

Data for the generation of the product
EO Data MOD09 (TERRA – AQUA): atmospherically corrected surface reflectance product 250m-500m resolution MOD02: reflectance band 1 km resolution for correction of cloud detection MOD03 : Geolocation dataset LANDSAT images (for validation activities)
Non-EO
Carthography, auxiliary data DEM (250 resolution) Land cover mask for: broadleaf, coniferous and mixed forest (250 m resolution)
EO Products Reference image snow free from MODIS images (250 m resolution) 8-days composite acquired in summer period.

Quality layers

Snow quality

- Based on NDSI
- High: NDSI > 0.7
- Medium: 0.4 < NDSI < 0.7
- Low: NDSI < 0.4

Cloud quality

- Based on cloud presence probability = p
- High: p > 95%
- Medium: 68% < p < 95%
- Low: p < 68%

Reflectance

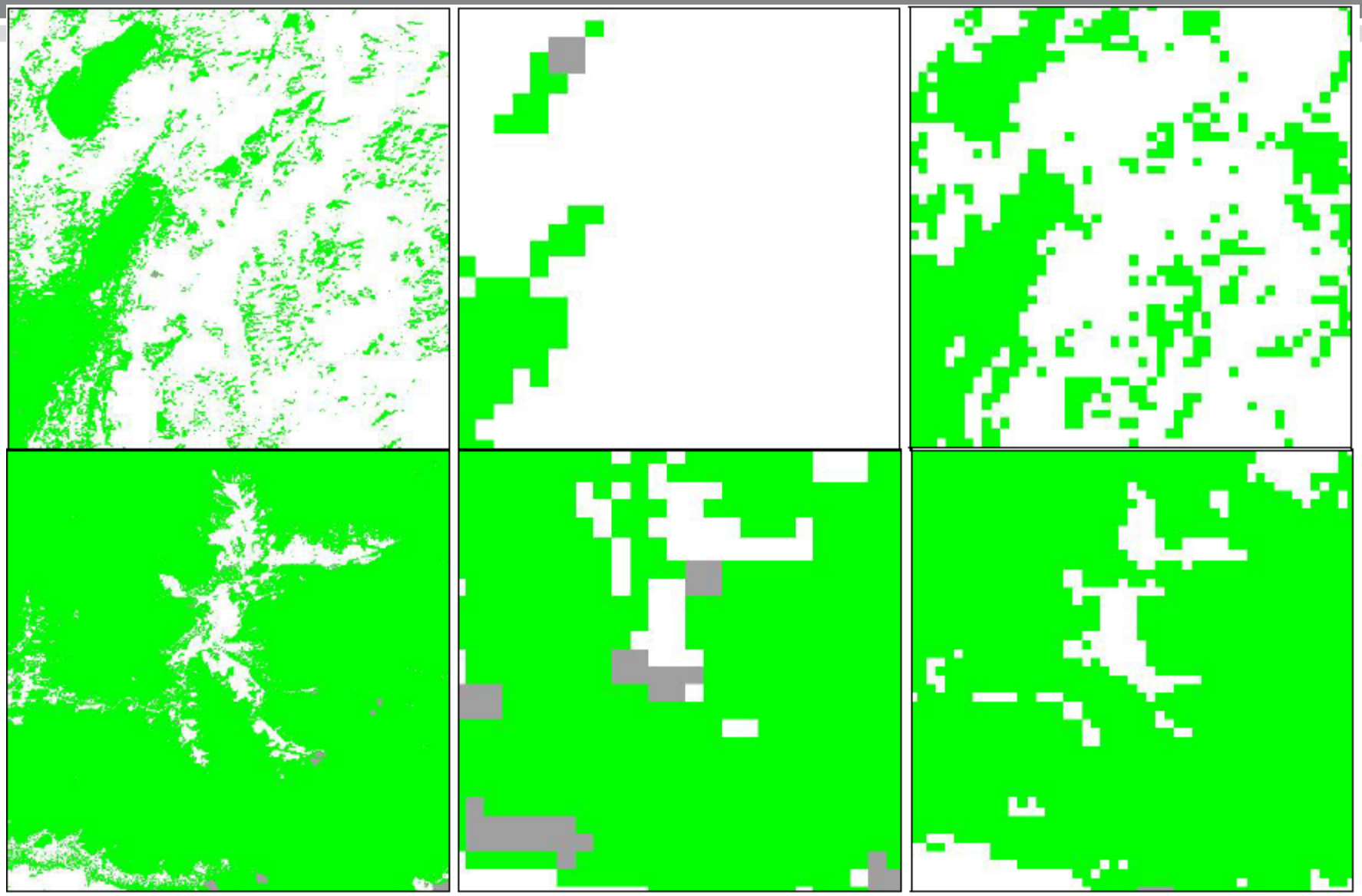
- No data
- Negative values

Geometry

- High: SolZ < 85° AND SeZ < 60°
- Medium: SolZ > 85° OR SeZ > 60°
- Low: SolZ > 85° AND SeZ > 60°

NDSI: Normalized Differential Snow Index; SolZ: Solar Zenith; SeZ: Sensor Zenith

Effect of improved resolution

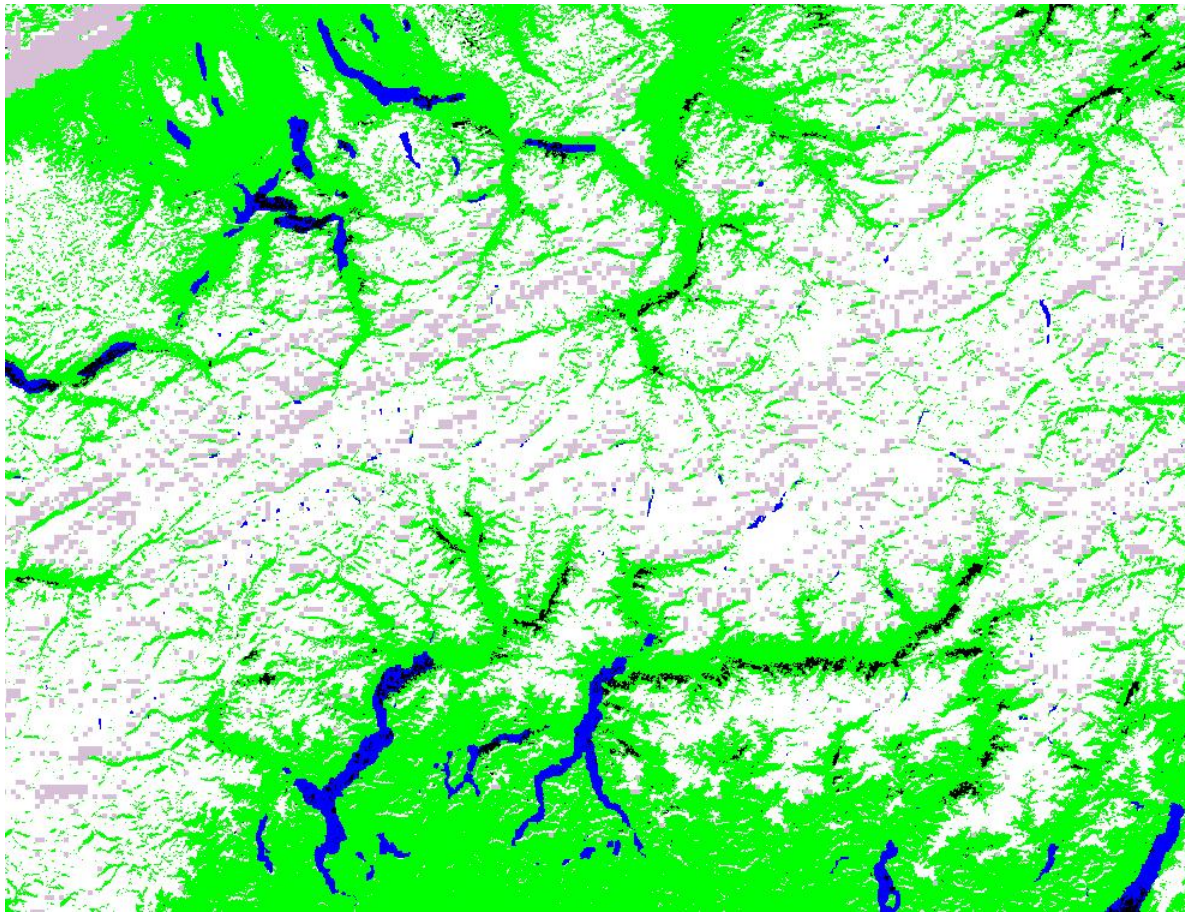


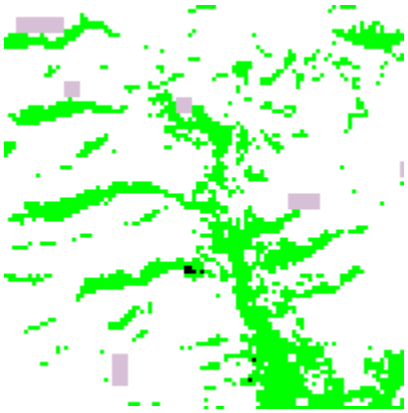
LANDSAT 30 m

NASA 500 m

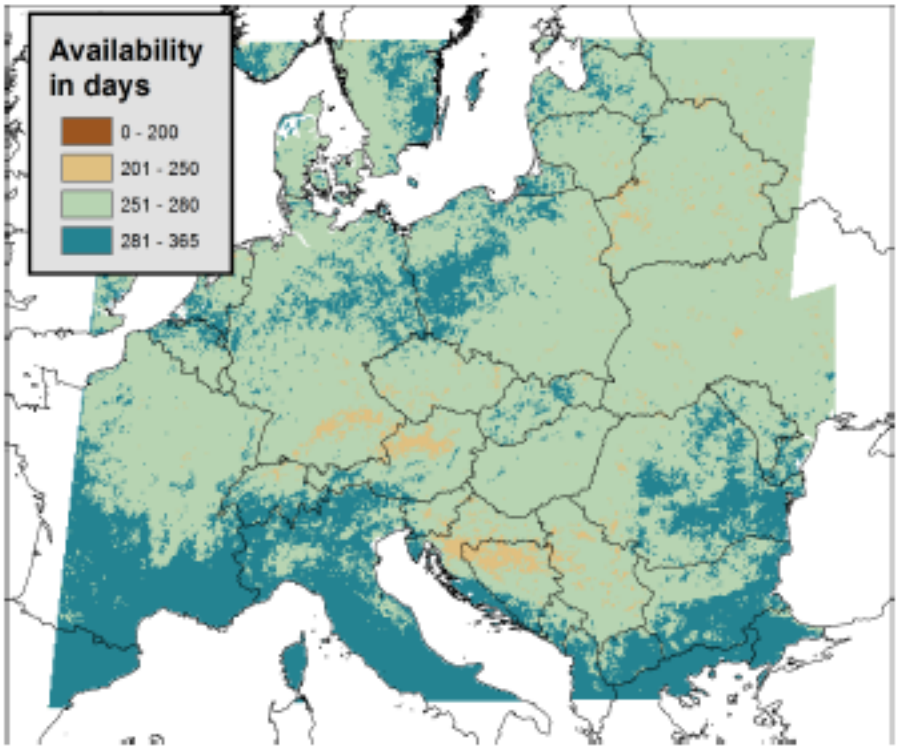
EURAC 250 m

Effect of topographic correction

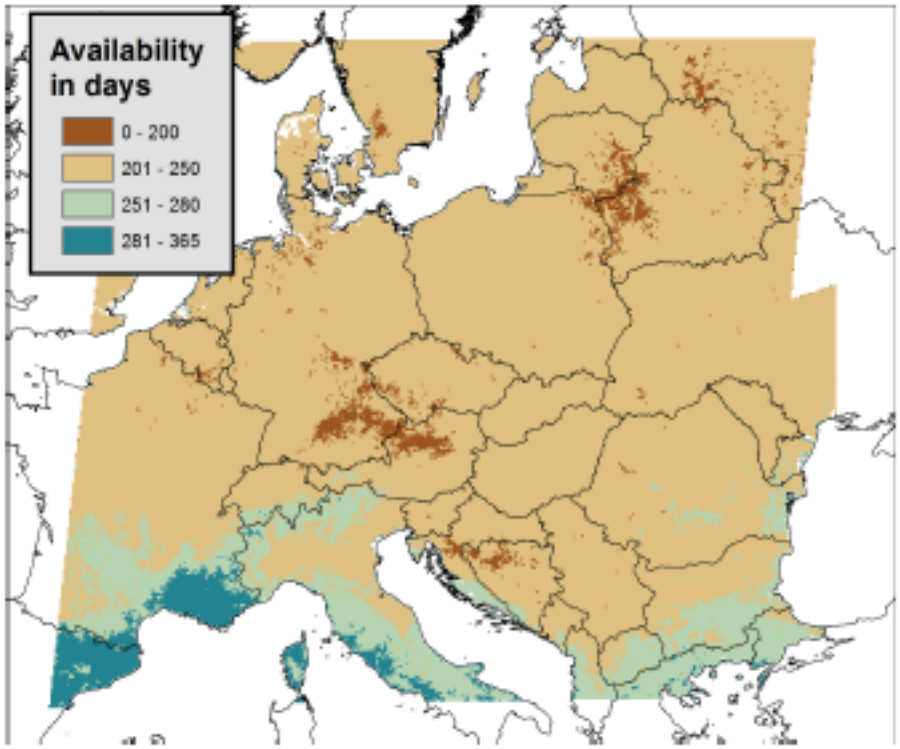




Results



EURAC-MODIS

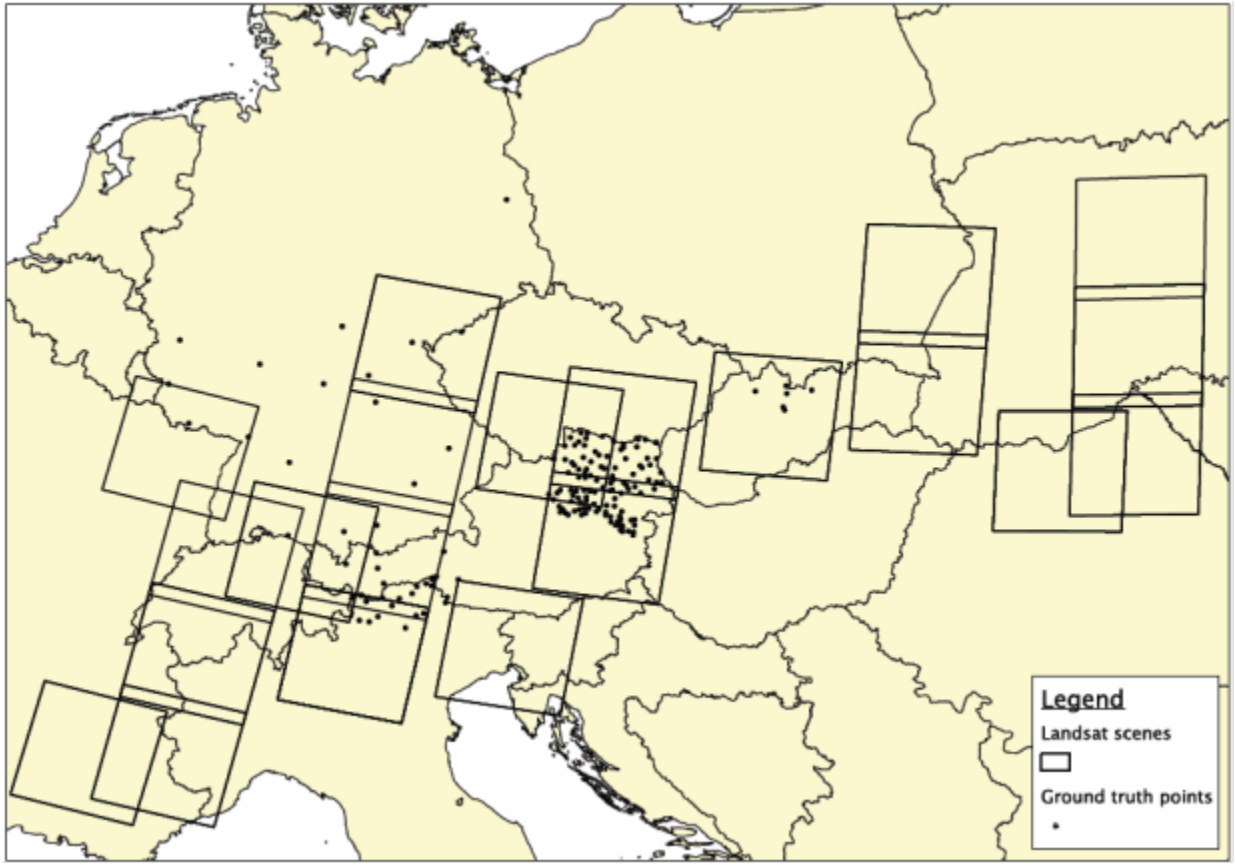


NASA-MODIS

G.Thirel, C. Notarnicola, M. Kalas, M. Zebisc, T.Schellenberger, A. Tetzlaff, M. Duguay, N.Mölg, P.Burek, A. de Roo, Assessing the quality of a real-time Snow Cover Area product for hydrological applications, Remote Sensing of Environment, Volume 127, December 2012, Pages 271–287

EURAC research

Validation activities

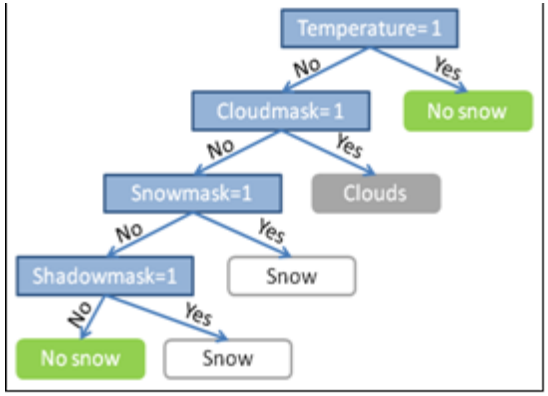


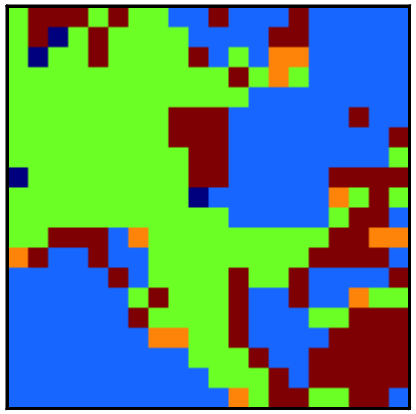
Validation activities

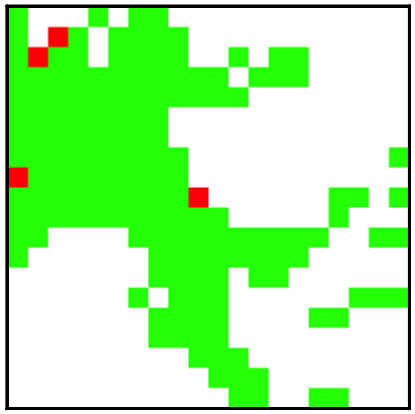
The validation activities are carried out by using:

- High resolution snow maps derived from LANDSAT images (16).
- MODIS standard products (on the same dates of LANDSAT images)
- 148 Ground stations in selected test sites where the presence of snow is detected. Stations have been selected in Italy, Slovakia, Austria, Germany.

LANDSAT algorithm







Areas masked out

Match “snow”

Match “no snow”

Mismatch MODIS “snow”, LS “no snow”

Mismatch MODIS “no snow”, LS “snow”

LS snow map: cloud, no data

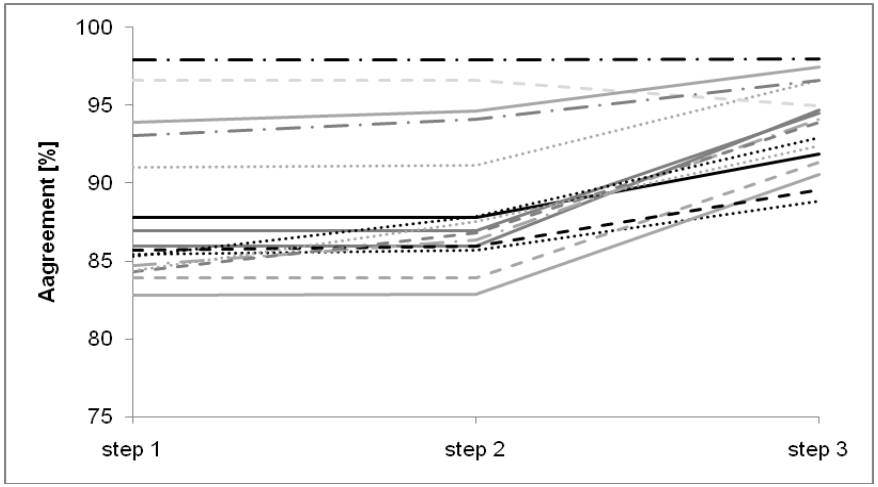
LS snow map: snow

LS snow map: no snow

Validation activities

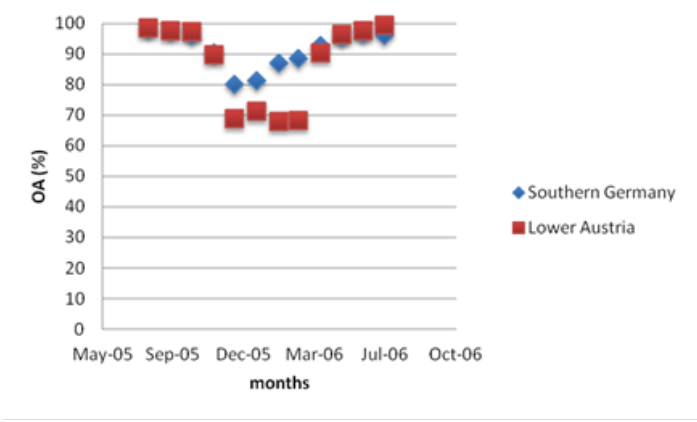
Comparison with Landsat snow maps

- Accuracy ranging from 88% to 98%, where most of the drawbacks come from the forested areas



Comparison with ground data:

- Overall agreements between the EURAC snow product and *in-situ* snow measurements range between 82% and 94%.

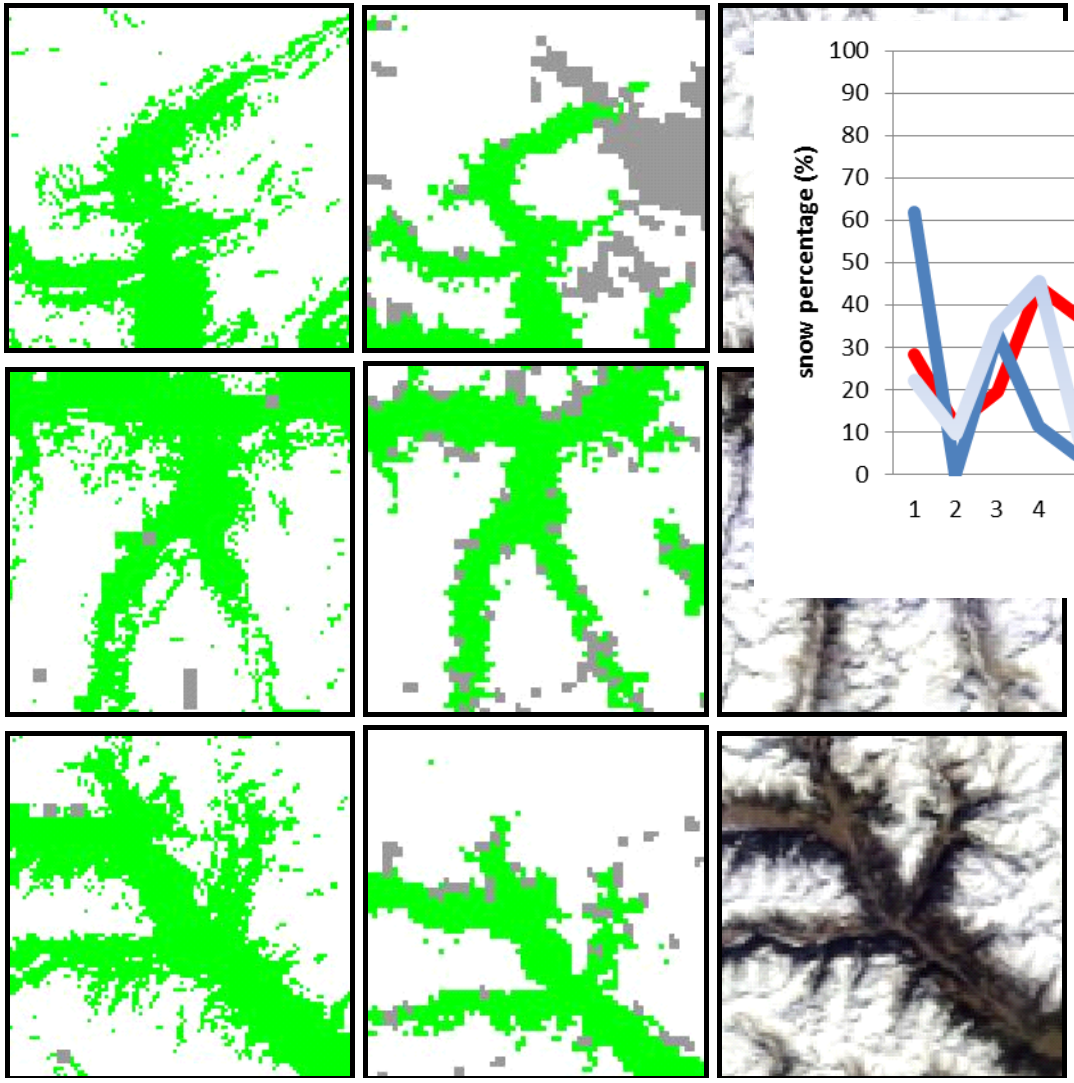


Comparison with MOD/MYD10:

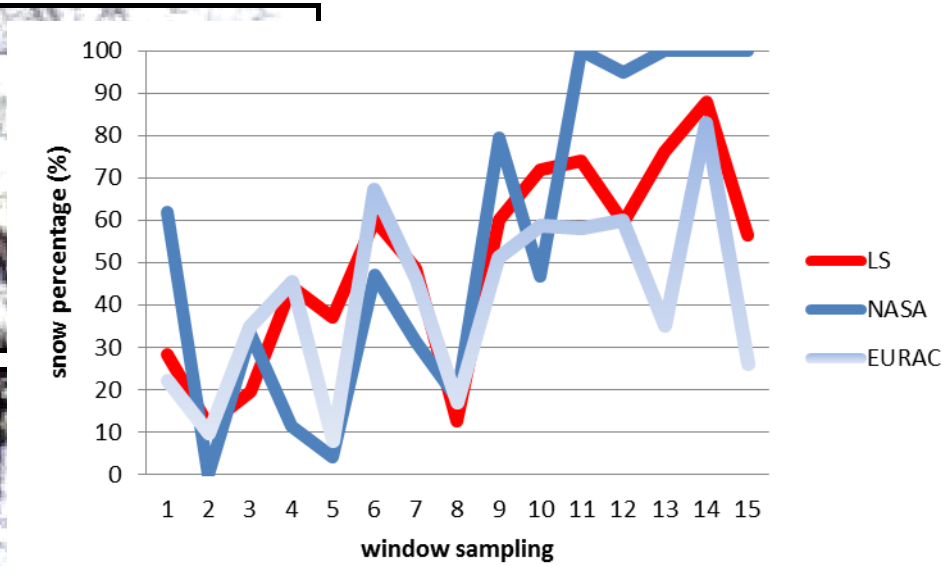
- Overall average agreement of 85.4%, where the commission is 4.9% and the omission error 16.2%. Outside forest, the overall accuracy is increased to 90.2%.

With new topographic correction the overall accuracy in average increase of 7-8 % including also forested areas. Work in progress, to be published soon

Results

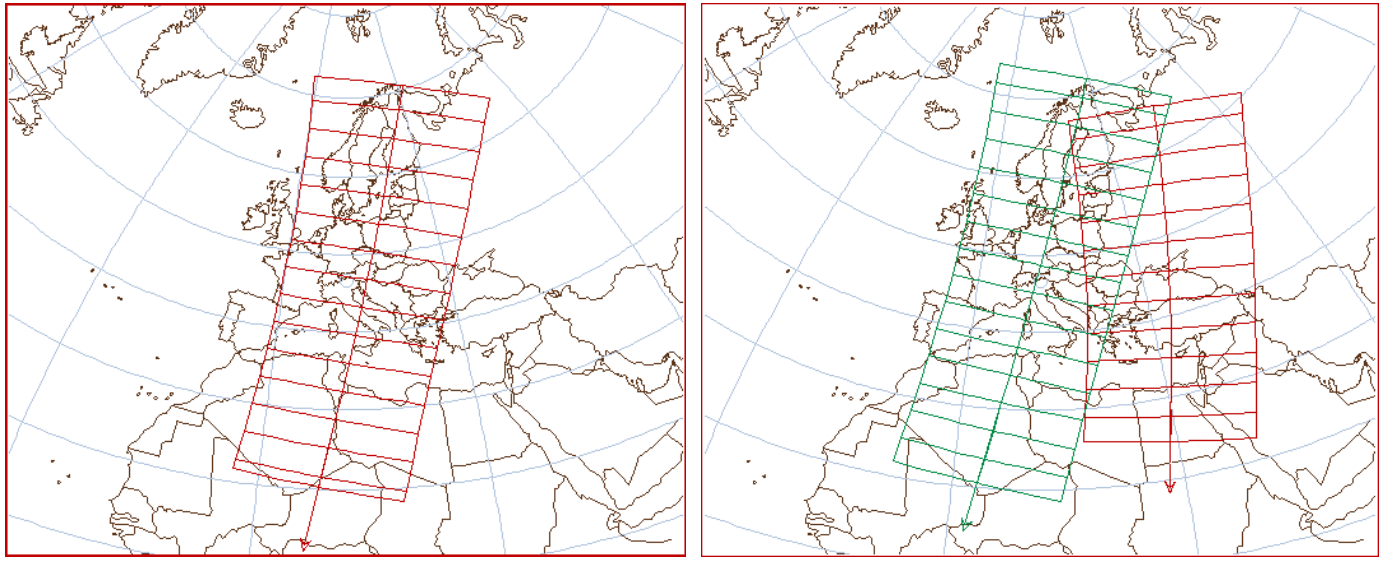


EURAC 250 m NASA 500 m RGB 500 m



RMSE Landsat-NASA: 25%
RMSE Landsat-EURAC: 16%

Product delivery



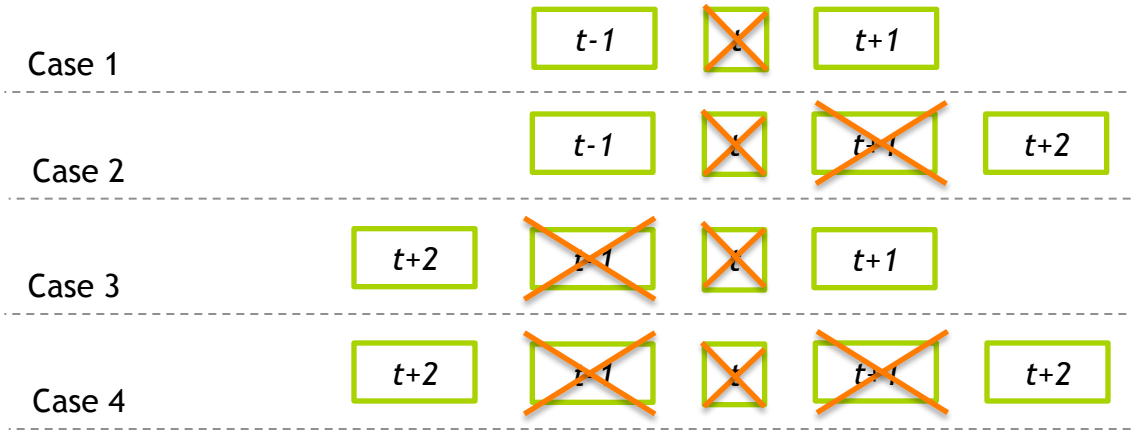
Satellite	Start Time	IM Delivery Time	IM Elapsed Time	CM Delivery Time	CM Elapsed Time
Terra	09:19	11:01	01:41		
Terra	10:57	12:58	02:01	13:07	02:10
Aqua	12:41	14:48	02:07	14:58	02:17

Cloud filter

- Clouds often obscure significant portions of the snow maps
- Clouds are removed following a two step temporal filter:

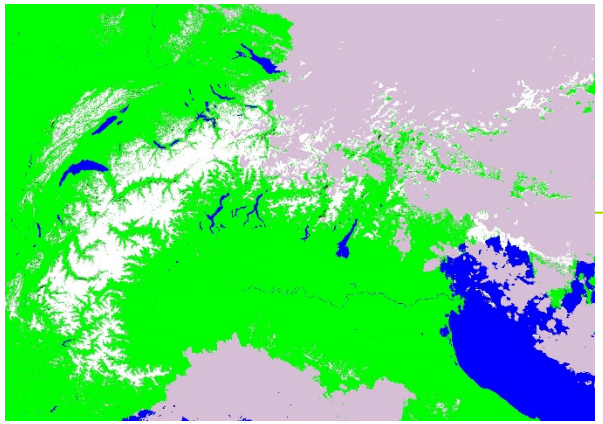
1. **Terra-Aqua merge**
   It takes advantage of the time interval (about 2/3 hours) between the two observations). In case of inconsistency between Aqua and Terra snow detection, the flag based on NDSI is used.

2. **Time interpolation**
   Only if the information before and after a cloudy pixel at instant *t* are consistent the value can be interpolated

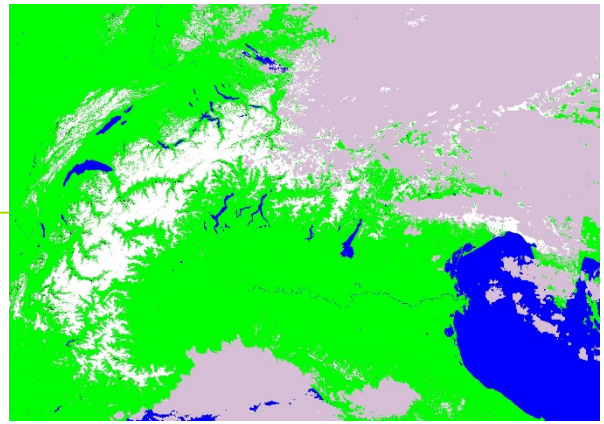


Cloud filter example

Date: 19-Mar-2005

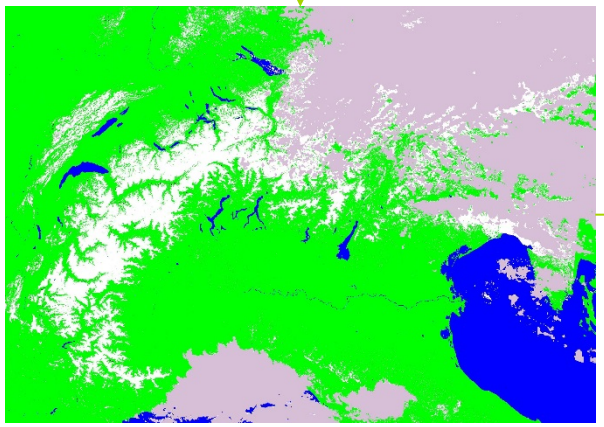


Terra (10:30)



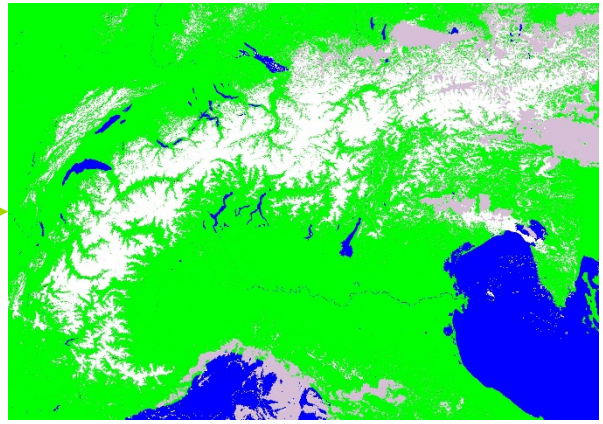
Aqua (12:10)

merge



Terra-Aqua merge

Time interpolation



Time interpolation

Strenghts and weaknesses

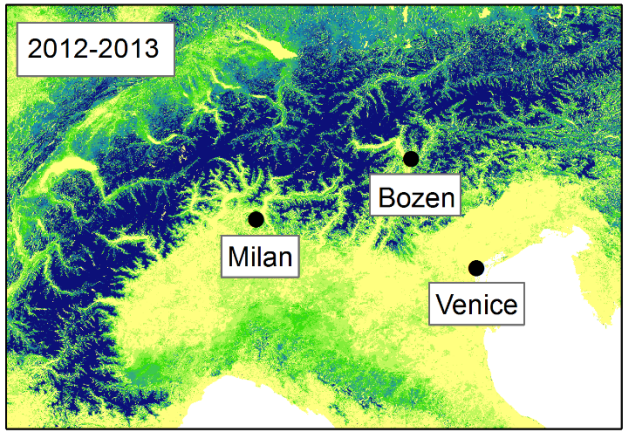
Strenghts:

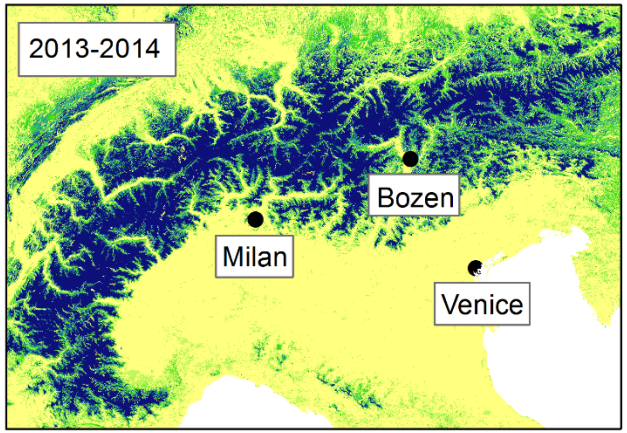
- 250 m useful for mountain areas
- Cloud screening adapted to Alpine conditions
- Improved topographic correction for MODIS bands

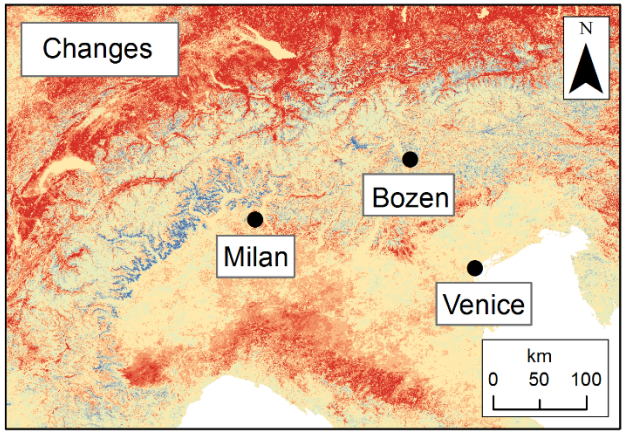
Weaknesses:

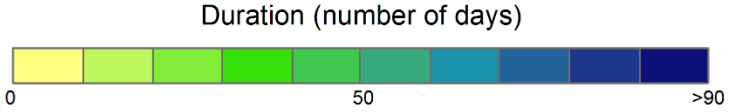
- Some limitations in detecting snow in forested areas
- Topographic correction cannot eliminate completely shadow effect in very steep slope especially during the morning acquisition (TERRA).
- Some misclassification snow-cloud.

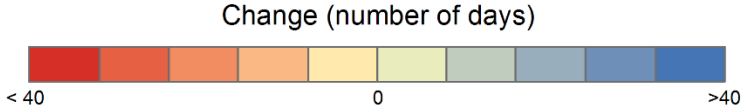
Example of applications











Conclusions and future works

- A new algoritm for SCA mapping based on 250 m MODIS images has been devepoled and validated.
- Improvements are especially found in patchy snow covered areas with respect to MODIS standard products.

Future works:

- Continuos validation for the recent improved approach
- Reduction of cloud coverage with temporal filtering and topographic features by using machine learning approaches;
- Cross-comparison with VIIRS snow cover maps; EURAC is acquiring the data directly from the receiving station.

Relevant References

Notarnicola, C.; Duguay, M.; Moelg, N.; Schellenberger, T.; Tetzlaff, A.; Monsorno, R.; Costa, A.; Steurer, C.; Zebisch, M. Snow Cover Maps from MODIS Images at 250 m Resolution, Part 1: Algorithm Description. Remote Sens. 2013, 5, 110-126.

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C.Notarnicola, D. Di Rosa, F.Posa, Cross-Comparison of MODIS and CloudSat Data as a Tool to Validate Local Cloud Cover Masks, *Atmosphere 2011*, 2(3), 242-255; doi:10.3390/atmos2030242.

EURAC research

MANY THANKS FOR THE ATTENTION!

QUESTIONS/COMMENTS?